Stochastic Geometry-based Trajectory Design for Multi-Purpose UAVs: Package and Data Delivery

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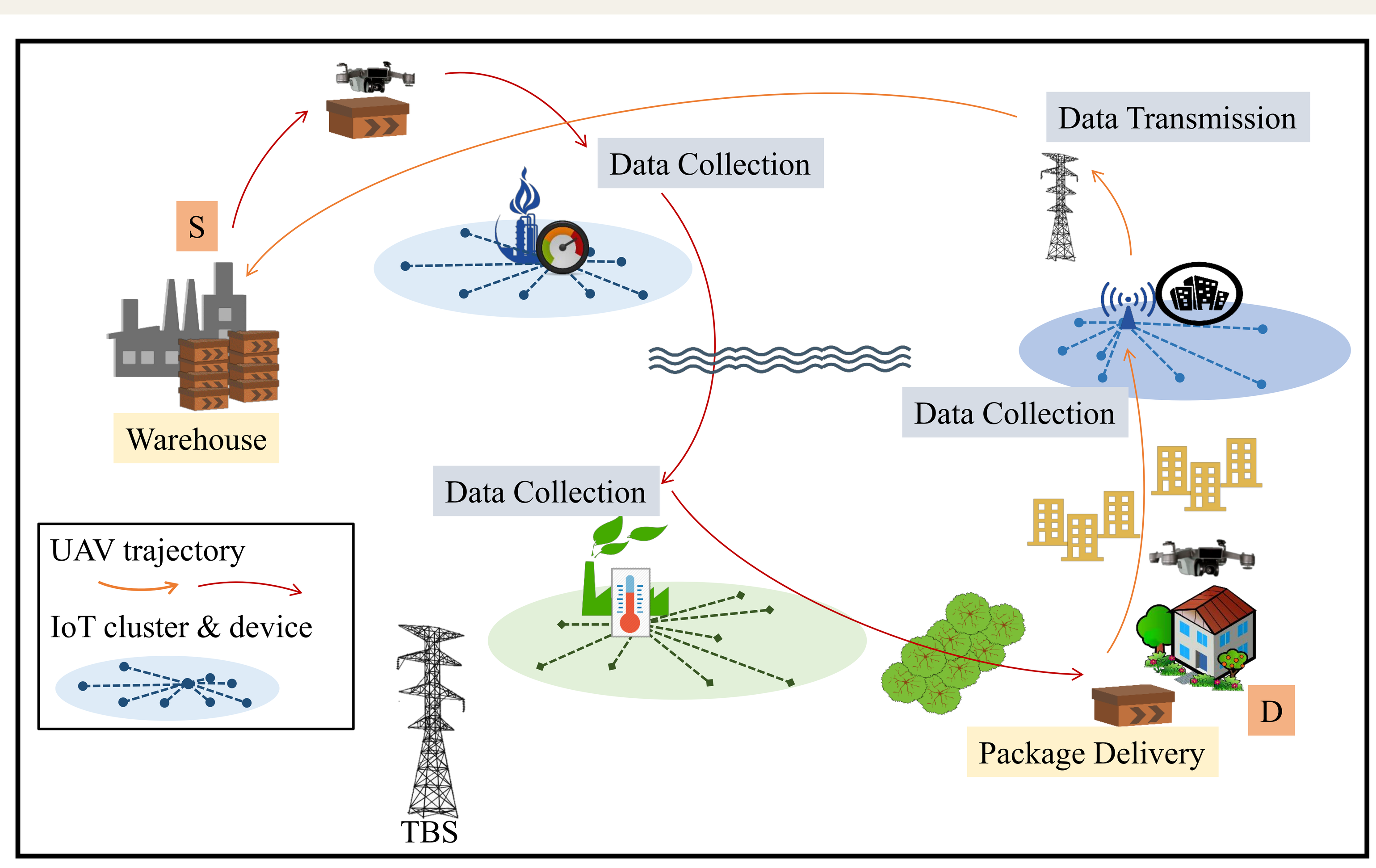
Introduction

Challenges of future UAV-enabled networks:

- Limited aerial space and physical infrastructure.
- The traditional model of dedicated drones for a single function faces is high cost and waste lots of energy.

Multi-purpose drones can be a solution: drones can be designed more flexibly to finish multiple tasks at the same time.

System Model



- Locations of two types of IoT cluster centers and TBSs are modeled by three independent Poisson point processes (PPPs) $\Phi_{i,1}, \Phi_{i,2}, \Phi_b$.
- Locations of IoT devices are modeled by Matern cluster process (MCP).
- UAVs deliver the package from the warehouse (S) to destination (D), while collect data from IoT devices and forward the data to nearby TBSs.
- UAV's onboard battery is limited.

IoT clusters & TBS Selection

- Order the IoT clusters/TBSs based on the distance and priority.
- UAVs costume all the energy to delivery the package and data.

Communication Model

- The transmission time between UAVs and TBSs/ IoT devices are M/C_t, M/C_i, where M is the data size and $C_{\{\cdot\}}$ is the maximal achievable data rate.

Trajectory Design

- Minimal time & maximum transmitted date path:

$$\mathscr{P}_1 : T^*_{\text{total}|\Phi_{i,1},\Phi_{i,2},\Phi_b} = \min_{\mathbf{h_t},\mathbf{s}} T_{\text{total}}, \quad \text{s.t.} \quad E_{\text{total}} \leq B_{\max},\ s_k \in \{0,1\}.$$

$$\mathscr{P}_2 : M^*_{\text{total}|\Phi_{i,1},\Phi_{i,2},\Phi_b} = \max_{\mathbf{h_e},\mathbf{s}} M_{\text{total}}, \quad \text{s.t.} \quad E_{\text{total}} \leq B_{\max},\ s_k \in \{0,1\}$$

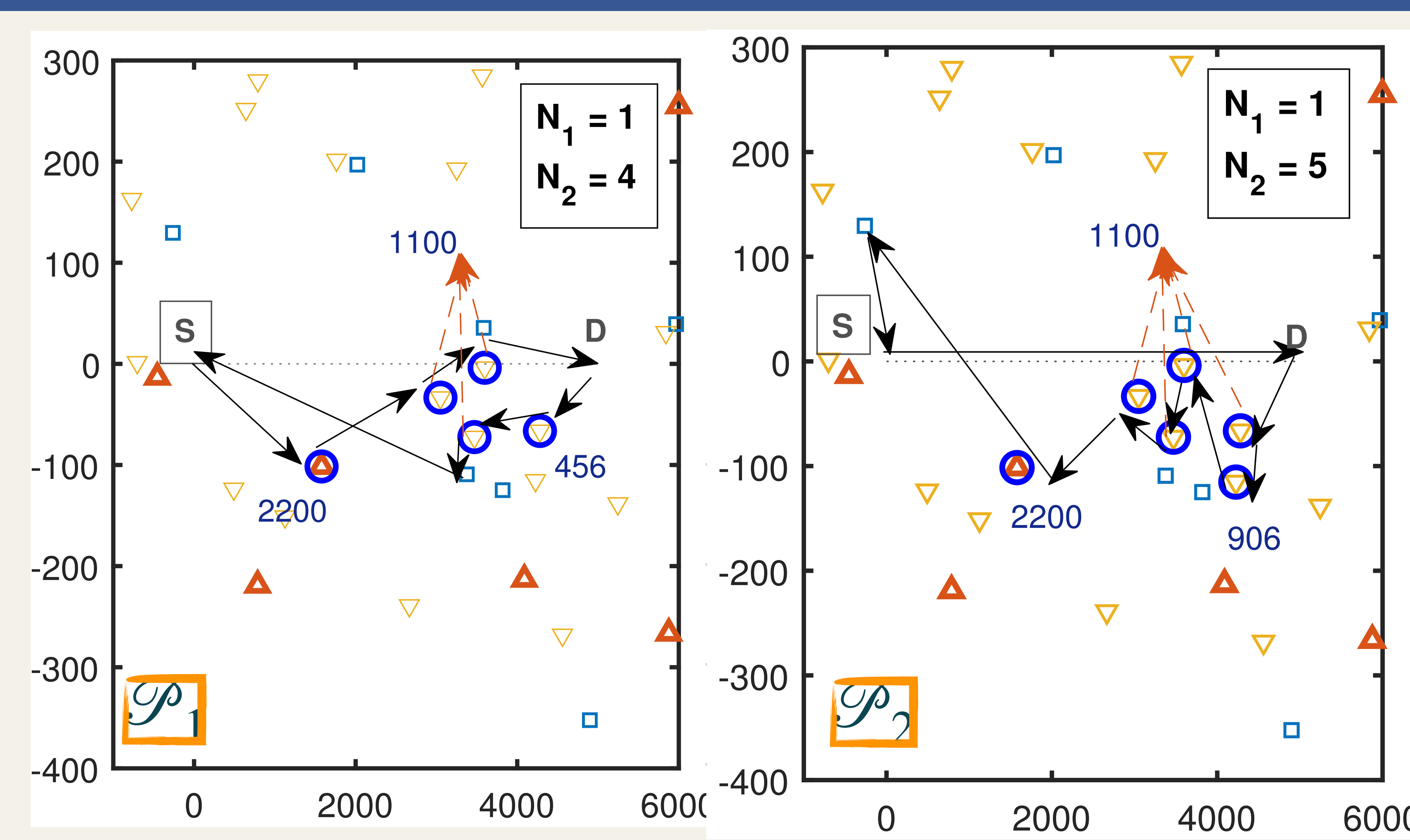
where T_{total} and M_{total} are the time and transmitted data of the trajectory, E_{total} and $B_{\max}$ are consumed energy and maximum onboard energy of UAVs.

Data Delivery Efficiency

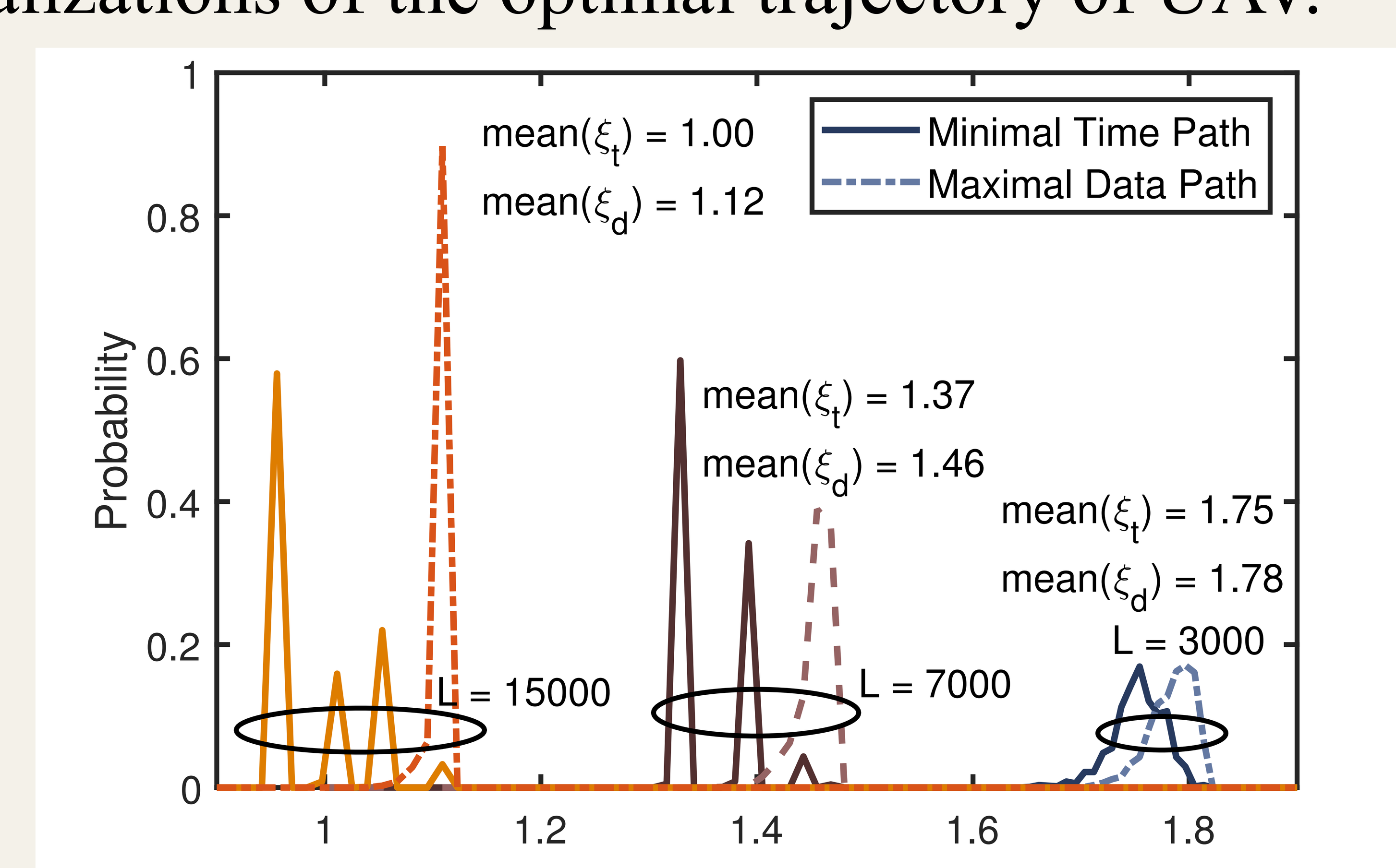
- Data delivery efficiency:

$$\xi = \mathbb{E}_{\Phi_{i,1},\Phi_{i,2},\Phi_b}\left[\frac{M^{*'}_{\text{total}|\Phi_{i,1},\Phi_{i,2},\Phi_b}}{T^{*'}_{\text{total}|\Phi_{i,1},\Phi_{i,2},\Phi_b}}\right],$$

Numerical Results



- Realizations of the optimal trajectory of UAV.



- The maximal data path has high efficiency under different L.
- The values of ξ_t for the minimal time path have several peaks because of the velocity.
- Minimal time path is more practical if the IoT data is limited and UAVs can delivery all of them.